Understanding the microphysical properties of developing cloud clusters during TCS-08

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LONG-TERM GOALS

To improve understanding of tropical cyclone genesis is through a research program that focuses on identifying the environmental and microphysical differences between developing and non-developing cloud clusters in the western North Pacific.

OBJECTIVES

The objective is to identify the environmental and microphysical differences between developing and non-developing cloud clusters in the western North Pacific. Specific investigations include:

1. detailed investigation of genesis using detailed observations gathered during the TCS-08 field campaign.
2. detailed investigation of genesis using remote-sensed observations from platforms that are maintained on a more permanent basis including satellite-based infrared, visible, and microwave imagers and long-range lightning detectors.
3. generalized study that aims to build an ability to detect and classify developing and non-developing cloud clusters using remote-sensing platforms alone.

Through diagnostic analysis of the detailed field observations combined with remotely-sensed platforms, insights will be gained that will contribute to improvement of the forecasts associated with tropical cyclone genesis, particularly in the western North Pacific Basin.

APPROACH

Our overarching hypothesis is that there are significant microphysical differences between developing and non-developing cloud clusters. If these differences can be identified with high-fidelity field

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14. ABSTRACT
To improve understanding of tropical cyclone genesis is through a research program that focuses on identifying the environmental and microphysical differences between developing and non-developing cloud clusters in the western North Pacific.

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observations then we can take two major steps to improve understanding of tropical cyclogenesis. First, we can investigate methods to identify the differences in developing and non-developing cloud clusters ahead of time. Second, because we can measure the mesoscale environment that the cloud cluster developed in, we can better understand the mesoscale environmental conditions required to form a developing cloud cluster, and we can investigate whether the vortex-stretching and concentration necessary for cyclogenesis occurs within mesoscale (100km – 300 km) stratiform updrafts, or whether it is first achieved on the smaller scale of convective scale (~10 km) updrafts that interact and contribute individually to the mesoscale vorticity concentration. The aircraft- and satellite-based observations that were gathered during the TCS 2008 field campaign (TCS-08: http://met.nps.edu/~tparc/TCS-08.html) will be analyzed for insights into relationships between near-cluster environment and convective activity within the cluster, and also for relationships between convective activity and overall intensification into a tropical cyclone.

WORK COMPLETED

A lightning study using the Long-range lightning detection network (LLDN) looking at differentiation between developing and non-developing cloud clusters for the eastern North Pacific 2006 season has been published (Leary and Ritchie 2009). This work is being extended to include more years to improve the statistical characterization of the cluster groups and more basins, in particular the western North Pacific, making use of additional sensors placed there for the TCS-08 field campaign.

An observational study of remotely-sensed microphysical characteristics of developing and non-developing cloud clusters has been started. An initial database of measurements from the DMSP, TRMM, and CloudSAT satellites is being compiled.

A methodology to automate the cloud cluster tracking is being developed for the entire Pacific basin. While the immediate application is to automate the lightning flash rate counts, the automated tracking will also support the broader remotely-sensed microphysical efforts. Current work completed include; stitching images from various geostationary satellites together to form a contiguous scene of the Pacific; and using the deviation angle variance technique described in a companion report to track cloud clusters.

RESULTS

Results using Vaisala's Long-Range Lightning Detection Network (LLDN) (Demetriades and Holle, 2005), have identified differences in the lightning flash rates associated with developing cloud clusters compared with non-developing cloud clusters both over water and over land (Leary et al. 2007; Leary and Ritchie 2008; Leary and Ritchie 2009a, b). In this study, categories of cloud cluster development are identified in the eastern North Pacific 2006 season using lightning flash rates as an indicator of activity. Four cloud cluster classifications: 1) NHC developers (those systems declared TD by the NHC); 2) non-designated developers (those TDs that NHC did not classify): 3) partial developers (systems that had some surface forcing associated with them, but never developed a persistent closed surface circulation; and 4) non developers (all other cloud clusters that persisted for 72 hours). Figure 1 shows the average lightning strikes for 6-h periods (times are UTC on the x-axis) for the 4 categories and then combining groups 1 and 2 and groups 3 and 4. There are higher flash counts for the period 0000 UTC – 1200 UTC because detection efficiencies are higher at nighttime.

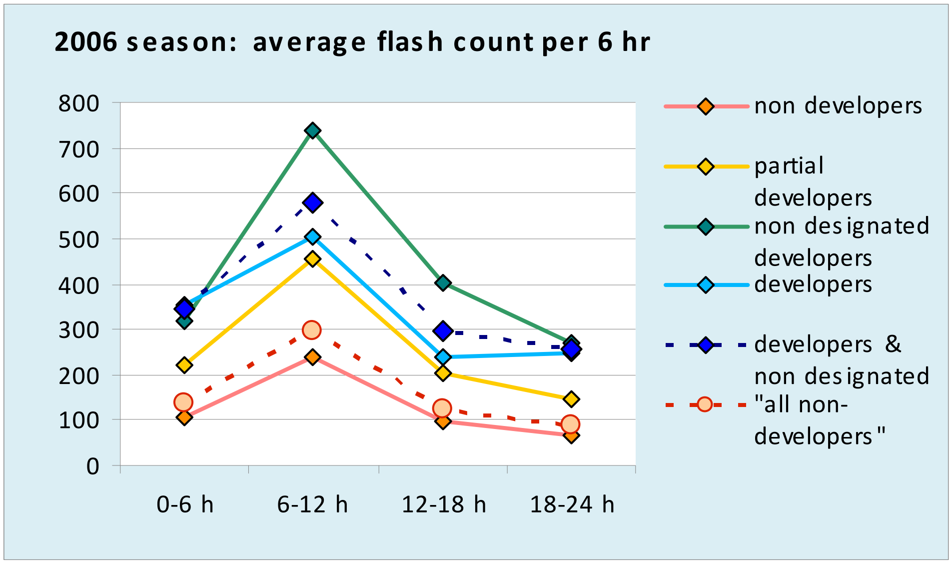

Figure 1: Average flash rates for 6-h periods for the 2006 season showing the four category classification in solid lines and combined developers (purple dashed line) and combined non developers and partial developers (red dashed line).

A clustering of the four groups into the two developing groups (1 and 2) and two non-developing groups (3 and 4) tested significant at the 5% level using a log-normal student's t-test (Leary and Ritchie 2009). The detection rates of these two groupings for various threshold values of lightning flash rates were calculated and plotted as an ROC curve (receiver operating characteristic curve – Figure 2). This curve summarizes the detection rate of developing cloud clusters (groups 1 and 2) compared with the false alarm rate (incorrect detection of non-developing clusters as developing clusters). The ROC curve (in tan) indicates an improvement over an earlier classification of group 1 compared to everything else (in black).

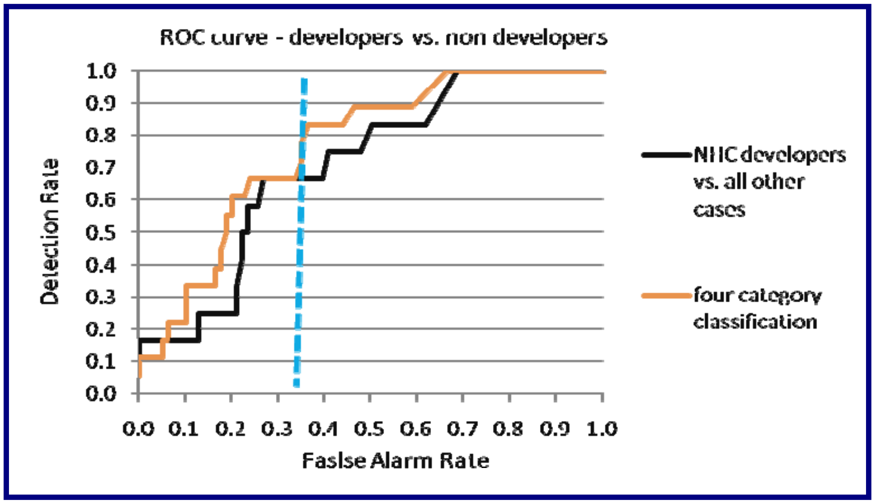

Figure 2: ROC curve for developing vs. non-developing cloud clusters using the earlier two-category classification (black line) and the final four-category classification (tan line). A detection rate of 86% and false alarm rate of 34% can be achieved using the four-category system (blue dashed line).

The thresholds were applied to "TCS" clusters in the western North Pacific during the TCS-08 field campaign for a period of approximately three weeks when lightning data were made available to the PI Leary and Ritchie 2009b). The LLDN systems in the western North Pacific are in preliminary testing phase, and there are some problems with the data south and southwest of Japan that still to be fixed. However, once systems that didn't last more than 72 hours were removed, preliminary results showed that the average flash counts over the lifetime of all TCS clusters in that period was 139/6h. Figure 3 shows a time series of 24-h lightning counts for TCS clusters during the period the lightning data were made available. TCS clusters are labeled by the names assigned during the field experiment. All developing systems are in a shade of blue, all non-developing in a shade of green. Those clusters that either did not last for 72-h or did not have at least 72 hours of data available because they were at the front or back of the period were excluded from this graph. In addition, any systems that were severely influenced by land or by the "Japan" effect were excluded. Three out of four systems that reached TD strength according to JTWC during that period had higher than the average flash counts and eight out nine systems that didn't develop into TDs had lower than average flash counts. Given the early nature and the small sample of data coming in thus far, this is a promising result.

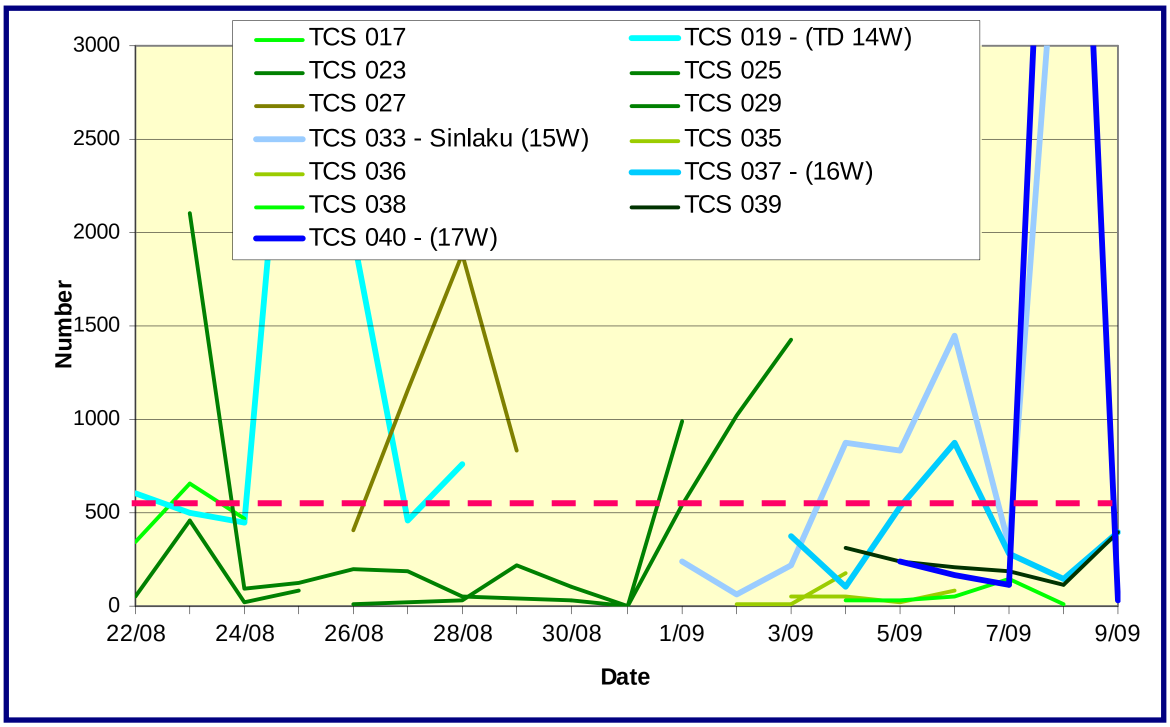

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Figure 3: Daily (24-h) flash counts for systems tracked during 22 August – 9 September in the western North Pacific during TCS-08. Thicker blue lines indicate the systems that reached TD according to JTWC and thinner green lines are non-developing systems. The pink shaded line indicates the average flash counts per 24-h.

GOES-east and west imagery have been merged into a single image to allow for robust tracking of the westward propagating features in that region of the world (Fig. 4). The final intent will be to include MTSAT images in the merged product so that seamless tracking of cloud clusters can be a accomplished to support the goals of: 1) lightning detection; 2) tracking of the microphysical properties of cloud clusters from space; and 3) the continued development of TC genesis and intensity detection from space using the DAV technique described in an associated report.

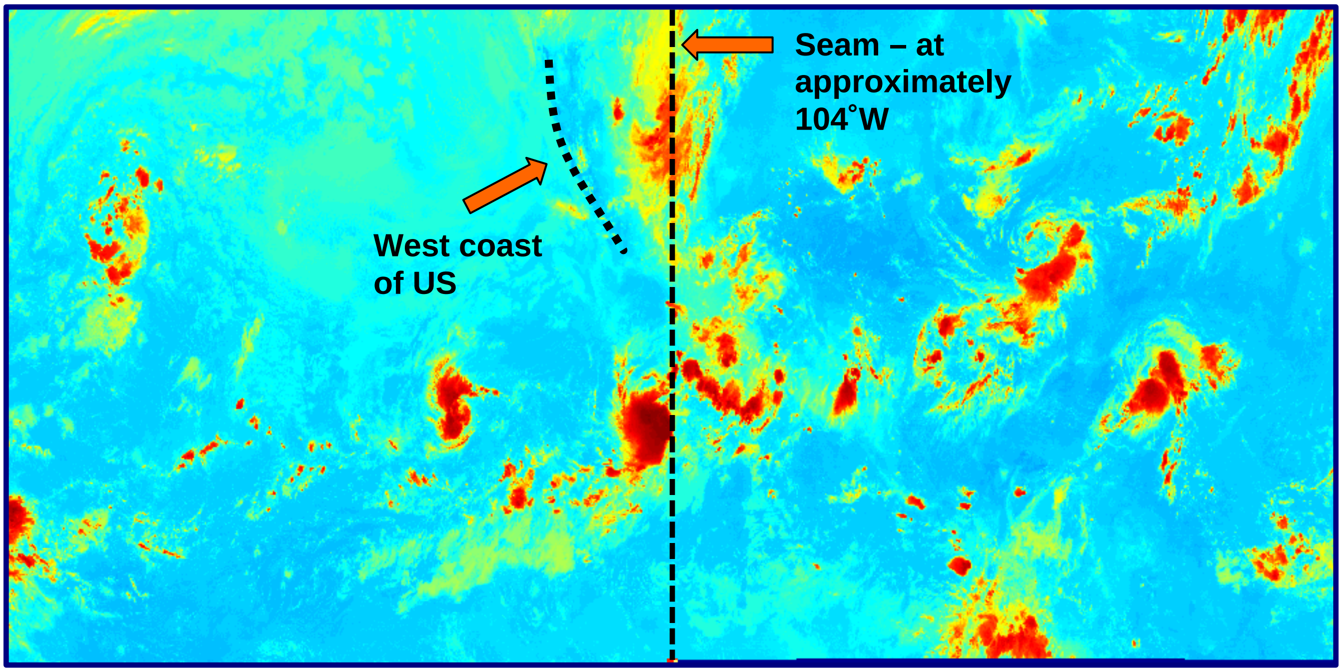

Figure 4: Merged GOES- East & West infrared imagery valid for 1 August 2006 at 1200 UTC.

In addition to the lightning data, geostationary and NASA A-Train data are being used to analyze the relationships between remotely-sensed effective radius profiles and convective intensity. The data are being used to quantify the spatial scales in the relationship between cloud-top effective radius and cloud-top pressure at various stages of organization in developing and non-developing clusters, building on the lightning work. We are testing whether these microphysical data - through the spatial scales of the vertical profile of effective radius - will give an indication of the organization of the convective cores of the systems. We expect to use these analyses as a basis for comparison with estimates of precipitation and convective intensity from the ELDORA radar. If the work is promising, we will extend the study to the Western Atlantic, where NASA research aircraft equipped with microphysical probes can make in-situ confirmations of the relationships seen in the satellite data.

IMPACT/APPLICATIONS

An observational study of North Pacific tropical cloud clusters is being conducted. The microphysical properties of the cloud clusters (as observed from remotely-based instruments as well as special field-program platforms) are studied to see if there are clear differences in the convective structure of cloud clusters that develop compared with those that don't. The documentation of high-resolution structural responses in the cloud clusters during tropical cyclogenesis will allow us to gain more insight into the physical processes that lead to genesis. The greatest value-added asset would be the development of a technique that will help to accurately predict genesis of tropical cyclones using remotely-sensed data. There is already potential for this technique shown with the use of the LRLDN data. Our plan is to add other data to improve the technique and make it more robust particularly for regions where the LRLDN has extremely low detection efficiency.

RELATED PROJECTS

Improving our Understanding of Tropical Cyclone Genesis N00014-07-1-0185, PI: Elizabeth A. Ritchie. This project uses high-resolution modeling studies to investigate detailed physical processes by which a tropical cyclone forms. The use of a mesoscale model allows high spatial and temporal data sets of developing and non-developing cloud clusters to be created that allow us the ability to investigate in detail the multi-scale processes occurring during genesis. The observational datasets collected during TCS-08 will guide and constrain the simulations produced.

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